Structural Modeling of the Optical Telescope Assembly (OTA) for the Next Generation Space Telescope (NGST)

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Primary Mirror Modeling

Center segment has 48 CQUAD4 elements & 96 CTRIA3 elements

Petals have 32 CTRIA3 elements each

Beryllium isogrid: 2 mm facesheet with 40 mm ribs

Plate elements have no shear thickness

Membrane thickness is 2mm

Bending thickness is 42 mm

PSHELL card has 2 mm thickness so MAT1 card has increased beryllium density (2771 kg/m^3) to account for rib mass

Beryllium elastic modulus = 321.25e+9 Gpa, Poisson's ratio = 0.0334

Radius of curvature = 20 m

Petal Reaction Structure

- Structural members modeled by CBAR elements for beryllium reaction structure
- Beryllium Elastic modulus, Poisson's ratio & CTE same as for mirror facesheet
- Beryllium density = 1856 kg/m^3
- Graphite/Epoxy reaction structure was modeled with CTRIA3 elements
- Gr/Ep sandwich had 1 mm facesheet with 4 mm core
- Gr/Ep PSHELL thickness was 2 mm, but bending stiffness & density were increased to account for core thickness
- Gr/Ep material properties obtained from Hexcel catalog

Center Reaction Structure

Gr/Ep sandwich reaction structure modeled by CQUAD4 & CTRIA3 elements

Sandwich facesheet was 3.2 mm thick with 150 mm core

PSHELL thickness is 6.4 mm, but bending stiffness includes core dimension. Density on MAT1 card reflects facesheet plus core

No shear thickness considered

Gr/Ep Elastic modulus = 55.85e+9 Gpa, Poisson's ratio = 0.1, Density = 2269 kg/m^3 (from Hexcel catalog)

Gr/Ep reaction structure was curved to radius of curvature of primary mirror.

New design will use beryllium. CBAR elements will replace the plate elements. New design will be flat, not curved to ROC.

Inner & Outer Box Beam Rings

- Inner & Outer box beam rings modeled as Gr/Ep members with CBAR elements
- Box beam cross section: 152 mm high, 100 mm wide, 6 mm wall thickness
- Gr/Ep Elastic modulus = 96.53 Gpa, Poisson's ratio = 0.32, Density = 1742 (from Hexcel catalog; this is a different type of Gr/Ep than used for center reaction structure)
- New design to incorporate beryllium I-beams and will be modeled with CBARs

Secondary Mirror Conical Mast

- Gr/Ep mast modeled with CQUAD4 elements
- Gr/Ep mast has 7 mm sandwich thickness: 1 mm facesheets & 5 mm core
- PSHELL card has thickness of 2 mm, but bending stiffness accounts for core thickness
- Shear thickness is considered
- Same Gr/Ep as used on center reaction structure except density (1619 kg/m^3) which is based on sandwich thickness
- Mast has 2 m diameter at base
- New design to incorporate beryllium CQUAD4 elements with thickness of 1.75 mm

Secondary Mast Longeron Blades

- Gr/Ep blades modeled with CBAR elements
- Same Gr/Ep as used for box beam rings
- Blade solid cross-section: 200 mm deep by 10 mm wide
- New design to change blades to beryllium
- New design to include circumferential wires to improve bending stiffness. These wires will modeled as beryllium CBARS

Segment Actuator Representation

- Each petal and center segment attached to actuators at 3 points.
- Actuators attached to reaction structure at 3 points
- Actuators are CBAR elements with zero density Titanium material properties: Elastic modulus = 113.77e+9 Gpa, Poisson’s ratio = 0.33, zero density
- Each actuator is modeled to be approximately 1 inch long
- CBAR degrees of freedom correspond to kinematic mount (2-2-2)
- OTA design incorporates 3 bipod actuators but model does not include bipods
- Current actuator models in no way reflect a real OTS actuator; future work will implement realistic actuator models.

Miscellaneous Components

Hinges, latches, drive motors, & interface between conical mast & center reaction structure modeled as RBE2 elements

Secondary mirror modeled as 8 CTRIA3 elements with mirror vertex constrained in twist DOF.

Secondary mirror previously modeled as zero density glass. Will become beryllium in future.

SIM tripod modeled as zero density Titanium CBAR elements

CONM2 mass elements added to hinges, latches, drive motors, secondary mirror & segment actuators (1 kg each for hinges, latches, motors, actuators; 15 kg for secondary mirror)

Old designs have OTA connected to SIM & spacecraft by same 3-point kinematic mount on inner ring via RBE2 elements.

New designs have OTA connected to spacecraft by 4 points on outer ring & to SIM by 3 different points on outer ring; SIM is connected vi RBE2 elements.

Material Property Values

All Gr/Ep data comes from Hexcel catalog

Titanium data comes from MIL-HNBK-5

Beryllium data comes from Brush Wellman data

Cryogenic beryllium CTE calculated from Brush Wellman data by integrating CTE over temperature range and dividing by the temperature range

Glass Primary Mirror Modeling

- Coarse mesh entire mirror & fine mesh a single petal
- Coarse mesh petal has 132 nodes, 220 elements, & 36 actuators per petal
- Coarse mesh center segment has 160 actuators, 560 nodes, & 560 elements
- Gr/Ep reaction structure
- Facesheet is 2mm-thick fused silica
- Fine mesh petal has greater detail than 132 nodes
- Compare results of coarse vs. fine mesh

Issues and Concerns

Is mirror facesheet mesh density adequate to yield accurate mirror deformations?

CME (coefficient of moisture expansion) has not been considered in evaluating Gr/Ep performance

CTE has always been assumed homogeneous. This is not likely in reality.

How well known at cryogenic temperatures are the material property numbers we are using?

Are boundary conditions of hinges, latches, and deployable mechanisms accurately represented?

Mirror coatings have not yet been addressed in the OTA model.